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# A method helping to define eco-innovative systems based on upgradability

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**Abstract**

Environmental issues due to emerging markets and rapid development of consumer goods' consumption require a new model to design more sustainable products. While traditional eco-design methods (LCA, Check-lists, Guidelines, DfX tools…) are generally restricted to a local optimization of the product or to macro-rules for defining an environmental strategy, this article presents an eco-innovative method based on product upgradability which is the integration of functional enrichments on the product. Indeed, the integration of upgrades offers new opportunities for facilitating the dissemination of the remanufacturing approach, the dissemination of Product-Service Systems, or for increasing the lifetime of product.
This article presents an eco-innovative method based on upgradability consisting in: exploring the potential upgrades of modules - PMoL (SADT activity A4), the potential value network structures for upgradability - VaNS (A3) and the potential serviceable upgrades including eco-learning strategies - SMoL (A5). This method combines then the results PMoL, VaNS and SMoL to form promising Upgradable Modules Scenarios – UpMoS (A6), which are completed by the specification of an associated value network (A7) and the consolidation of eco-usage services and services offers (A8). The final result obtained, Upgradable systems concepts– UpSys are then assessed thanks to a multicriteria approach (A9) considering environmental, economic and user's and stakeholder's attractiveness criteria.
To summarize, this method is structured in two rounds. The first round (A3, A4, A5) aims to explore widely the possibilities offered by the upgradability avoiding the complexity of an approach dealing with several parameters simultaneously. The purpose of the second round (A6, A7, A8, A9) is to specify and assess Upgradable systems encompassing the overall results of the exploration. Before performing this work, relevant information needs to be collected for the project (market information, customer segments, technologies, stakeholders, environmental impacts of the current product, etc.) and acceptability domains of upgradable systems have to be analyzed (A1, A2).
This paper presents therefore this eco-innovative approach based on five founding principles and answering to the requirements identified in the literature for a good and effective eco-design method.


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*Keywords:* Eco-design; Upgrades; business model; eco-usage; PSS.

## 1. Introduction

The introduction of the environmental dimension in product design is a fundamental priority in our society. Some measures to reduce the impacts were adopted since around ten years within companies subjected to the public pressure of the policy, the regulations always more restricting and the sensibility of the population in ecological concerns. These measures rely on the development of reprocessing sectors (collecting, recycling and remanufacturing), on the elaboration of new materials (Biofuels, biodegradables materials, ecomaterials) [1] on the development of new manufacturing processes (cold injection moulding, thin film deposition), on mechanisms allowing to change the direction of user's behavior (ecofeedback) [2] [3] etc. The current ecodesign methods available for the designers are numerous; however they do not allow to cover all these aspects (materials, processes, usage, end of life) and, consequently do not answer


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completely the requirements of a complete ecodesign method. Facing with the accelerating rhythm of products renewal, which causes accelerated exploitation of materials and energy. (today, with an annual consumption of raw materials of approximately 60 billion tons, the world population consumes about 50% more natural resources than 30 years ago [4]), we claim to change current patterns of consumption and mass production. We propose to consider another mode of production / consumption based on upgrade, functional enrichment brought to the product overtime: the Dynamics of Continuous Upgrades Integrated in Sustainable Products, that is to say, a product with a lifetime projected on the medium/long-term through optimal modularity. With these products, technical, visual or functional improvements could be "easily" integrated to adapt the system to changes; in particular the consumer needs changes. Upgradability is promising to add value for customer and producer, and represents new green opportunities. With upgradability, it would be possible:

- to have, at any time, the most efficient technologies in term of energy consumption,
- to extend the lifetime of product taking into account not only reliability of parts but the obsolescence too,
- to build eco-learning strategy for user modifying product in function of its behaviour,
- to optimize the end-of-life treatment of material because replaced modules induce more frequent and better controlled use of remanufacturing and/or recycling channels
- to increase the generation of services “linked to the product” which represent an opportunity for industrial companies who want to switch to offers with more services: services based on sensors upgrades in the spirit of “connected objects”, services related to a better consumer understanding due to a closer relationship company-consumer, service related to the upgrades integration itself.

After presenting upgradability as opportunity to design eco-innovative system (section 1), we define the requirements of a good ecodesign method (section 2). The five founding principles of the new proposed method helping to define eco-innovative systems are presented in section 3, and the description of the nine Actigrams in section 4.

## 2. Requirements for a good ecodesign method

### *2.1 Definition of the macro-criteria*

What’s a good eco-innovative design method? A good eco-innovative design method must be exploitable by the design team and provide innovative solutions, which cover a wide environmental scope (several environmental dimensions).

To assess current eco-innovative design methods it is necessary to define the functions that they assure for the design team, and more widely the industrial organization. General requirements expected from an Ecodesign method and formulated by Ernzer [5] are the ease to learn, understand and use, lead to relevant, non abstract and understandable results, the usability in early phases of the product development process or by Fargnoli and Kimura [6] are the effectiveness of the method in assessing environmental performance, the usability, the possibility to review the design activities, and the ability to provide new solution, the ability of the method in fitting into a certain design process. Others requirements are the multidisciplinary implication, the ability to correctly define the performance of product in a exhaustive way. Indeed, ecodesign has an impact in the various departments of the company and an ecodesign method must be a tool helping the multidisciplinary design team to take into account all different aspects of the product on the life cycle associate (R&D, Marketing, Customers services, Purchases, Supply chain, Innovation etc.). An environmental expert must be integrated in a design team, who can be an internal person to the company or to intervene as to external advisor; in this last scenario it is necessary to establish a learning support allowing to train the members of the design team. We retain the following criteria to characterize the method exploitation by a design team: the multidisciplinary implication, the design process support and the scope of the design process.

Concerning the method capability to generate eco-innovative solutions, certain authors show the impact of the approaches which are situated in the early design phases and defines the various levels of Ecodesign [7] [8]: Products improvement (level 1) requires an adjustment of the existing products. The redesign of products (level 2) involves that the components of the product are developed or replaced by others. These two levels concentrate exclusively on products. On the other hand, the functional innovation (level 3) aims at replacing the services proposed by products, the innovation of the systems (level 4) involves that new products and services appear, requiring modifications in infrastructures and organizations.

To be “complete”, an ecodesign method must cover several environmental dimensions, a wide environmental scope. Does it allow to report all the environmental dimensions of the problem? The approach that we wish to put in to the test aims at handling the overall phases of the lifecycle of a system. An ideal method would handle simultaneously technological, functional/usage, economic, environmental and organizational dimensions.

### *2.2 Ecodesign methods assessment*

The state of the art in eco-innovative design approaches shows the existence of numerous approaches, encompassing methods and tools that are not necessarily at the same level. These main developed eco-innovative product design approaches are estimated through an evaluation grid considering the above defined macro-criteria. Three types of approaches have been distinguished (Table 1):

- LCA oriented Ecodesign approach
- Innovation oriented Ecodesign approach
- DfX oriented Ecodesign Approach

The first tools consist in exploiting in a iterative way a software of Life Cycle Assessment. The LCA tools applied to the current product indeed allows to identify the most impacting components and life cycle stages. Alternative solutions can be proposed; their environmental gain can be

finally assessed. Through a multicriteria evaluation led on the whole life cycle, it allows a rigorous identification (standardized methodology ISO14040), but this approach based on LCA tools uses up too much of the design team's energy as they concentrate on understanding the reasons of environmental impact [9] of past products. This is detrimental to their work of interpreting and seeking means of improving future products [10]. The scope of LCA tools is only the assessment. None innovation axis or potential solution are suggested to the design team.

Table 1: Assessment of ecodesign methods according to eco-innovative design method criteria

| Tools and Methods considered | | Eco-innovative design method criteria | | | | | |
|---|---|---|---|---|---|---|---|
| | | Multidisciplinary Method | Design support | Complete or not design process | Stage of design Process | Level:Optimization, Improvement, Innnovation | Environmental Scope |
| LCA Ecodesign approach | LCA [11] | Environmental expert (internal or external) | Need LCA knowledge<br>Environmental expertise<br>Time consuming | At different time in design process | Late in design process | Optimization | All phases of the life cycle<br>Eco indicator<br>CML, EI99 (quantitative) |
| Innovation oriented Ecodesign approach | QFD E [12] | Design team<br>Environmental expert | QFD Guidelines | Design process | From early design process | Improvement<br>Innovation | All phases of the life cycle<br>Mono-criteria (qualitative or quantitative) Method EI99 |
| | LiDS-Wheel [7] | Design team<br>Environmental expert | Step by step guidance | At different time in design process | From early design process | Improvement<br>Innovation | Base of rules on Materials, Energy, EoL |
| | Eco-Compass [10] | Design team<br>Environmental expert | Step by step guidance | At different time in design process | From early design process | Improvement<br>Innovation | Rules on Materials & energy |
| | Eco TRIZ [13] | Design Team<br>Environmental expert | Guidelines & Software tool | At different time in design process | Early design phases | Innovation | All phases of the life cycle |
| | Eco-ASIT [14] | Design Team<br>Environmental expert | Guideline | At different time in design process | Early design phases | Improvement<br>Innovation | All phases of the life cycle |
| DfX Oriented Ecodesign approach | Prodtect [15] | Design Team<br>Technical expertise | Software tool | Design process | Late in design process<br>design detailed stage | Optimization<br>Improvement | Material, Fixtures<br>End of Life optimization: reusable part, recycling parts and hazardous substances |
| | DfM [16] | Design Team<br>Environmental expert | Software tool | Design process | Late in design process | Optimization<br>Improvement | Manufactured phase<br>Aggregated Method EI99 |
| | Eco use [2] | Design Team<br>Usage expert | "Design Interventions" axis | At different time in design process | Late in design process | Improvement | Usage phase |
| | PSS design methods [17 [18]] | Design team<br>Services expert | Abstract design method (focused on Services) | Services design method<br>PSS design method | Early design phases | Systems Innovation | All phases of Lifecycle with comparative functional Unit |

While the traditional ecodesign methods allow a superficial environmental improvement of the current products, the eco-innovation is an approach, which allows identifying innovation axis to decrease radically the environmental impacts while offering some added value to the users and to the economic actors of the product [19]. Among these tools of the product life cycles environmental QFD, Eco-TRIZ or Eco-compass is most often found in the literature. With these approaches can be initiated innovation actions, at different times in design process, but they don't form a design process strictly speaking.

By contrast, another category of approaches describes the design process focused on an *a priori* green goal. They are named "design for X" (Dfx) methods. These last years, the development of tools focused on end of life optimization. The emergence dismantling optimization methods (DfD) [15] as well as of design of modular products (DfM) [20] [21] aim at reorientating the end of life of products towards a better management of the recycling and more at privileging the re-use of modules. For the PSS design, a range of methodologies exist but companies fail to consider the whole system [17]. These approaches are complete design guide but they are centred on one goal and the scope of innovation is constrained. For example, new end-of-life scenarios as the remanufacturing of modules imposes an adaptation of the reverse logistics networks with all the consequences that it involves in terms of infrastructure, localization and management of flows, new partners finding or new business model building. But DfD tools are focused on optimization of product architectures according to product characteristics and the end-of-life strategy, and they generally do not go beyond a simple optimization of the dismantling sequences.

The study of some tools shows some limits of the current methods (cf. Table 1) to match the requirements of design of eco-innovative systems. The LCA approach is used after design process, innovation oriented ecodesign approaches provide innovation axis, not a design process, and DfX approach deals with only one or two environmental dimensions and doesn't satisfy all the functions design "global" innovative system.

For answering simultaneously to the requirements of a good eco-innovative design method, five principles were formulated as foundations for our new approach based on upgradability.

## 3. Definition of the founding principles of the new proposed method

Our method is the synthesis of studies and workshops with two industrial companies B2B and B2C in an action-research way. In particular the upgradability influence on technical, business model and eco-usage dimensions has been studied.

### *3.1 A workable guide helping the designers*

The method has vocation to help the design team to develop more relevant solutions. In this particular case, it has to help the members of the "extended" design team (R&D, Marketing, Supply Chain, Customer Services, Business etc.) to define the various dimensions of the problem, to generate innovative solutions from new ideas and to assess then to select the most promising on the environmental and economic aspects and which satisfy the users and the other actors of the

life cycle of the product. The structure of the method has to give to the design team the guidelines to execute the task of the method: which data to gather and how to use them to create new solutions, when and how to estimate these solutions and finally how to determine the most relevant solutions for a specific situation. The guidelines can be supported by simulator tools for the critical tasks (shown at the bottom in Figure 1).

*3.2 A multi-dimensional and exhaustive design method without a priori knowledge*

The strategy used for this new method consists in privileging no solution a priori. The method is structured in two times. ROUND 1: The method is based on the separate developments of a list of potential Value Network structures (VaNS), a list of potential upgradable Product Modules Lines (PMoL) and a list of potential upgradable Service Modules Lines (SMoL). The idea is to explore widely and independently new topics (VaNS, PMoL and SMoL) to open in a most exhaustive way the design space and to identify new opportunities to eco-innovate. ROUND 2: the definition of potential Upgradable Modules Scenarios (UpMoS) is obtained by association of these results, aggregating consciously the multidisciplinary points of view. After that, are specified the business model aspects and associated services, in particular eco-learning strategy. The final result of this new method is an Upgradable System (UpSys = detailed Value Network + UpMoS + Added Services + Eco-learning service).

*3.3 A multidisciplinary approach*

The design methodology proposed rely on a benchmark of the current product (in terms of usage, product architecture and end of life management) made by all the disciplines involved on the design process. This strategy aims at involving all members of the “extended” design team, guaranteeing a wider exploration (Round 1), a more precise assessment (Round 2) and progressive evolution of the current industrial system towards a future greener industrial system.

*3.4 A method to act in early design stage*

The objective of this method is to help the design team, in the early design phases; the final report of this method is the best concept of Eco-innovative system (Upgrades scenario of Modules and services and associated Business model) on the economic and environmental aspects and on users’/stakeholders’ attractiveness. We focused our efforts on the earlier stage because it corresponds to the stage where the freedom degrees of the design team allow to envisage eco-friendly solutions radically new. In fact, innovation can be the result of the wide and independent exploration of new topics (ROUND 1) and of the combination of these outputs to form the 9 blocks of a new business model (ROUND 2) according to Osterwalder [22].

*3.5 An Environmental assessment but also on Economic and Attractiveness aspects*

The method encompasses various aspects of the environmental concerns. Are proposed the improvement of the lifetime by upgrades of modules and services (A4&6), the improvement of the environmental consciousness by ecolearning service (A5&7), or implementing business model including end-of-life treatment to reduce the impacts generated in End-Life (A3&A8). These "green" innovation axes are based on the adaptability of the product, supported by its modular structure.

The final output of the method is one (or several) concept of Eco-innovative system viable: by viable, we understand a system which is at once acceptable on the economic criterion for the company (and for stakeholders), better for the environment and for all stakeholders implied in one or several life cycles of the product and finally attractive for the user (first and others cycles). The various concepts proposed are classified in a trihedral (economic, environmental and attractiveness criteria).

## 4. A method helping to design eco-innovative systems

The general structure of the method is based on 5 founding principles expressed in the chapter 3, contains 9 stages. The SADT formalism (Figure 1) is used to synthesize the main inputs, outputs, resources and controls of these 9 actigrams.

*4.1 A multi-dimensional assessment of the current system*

This analysis must be driven by integrating all disciplines and the services of the company. This stage serves just as much to federate all the actors of the design team that to take in all the information necessary for the following stages.

*4.2 Definition of acceptability domains of upgradability*

From the analysis of the current system (reliability, cost and environmental impact of the product parts; cost and environmental impact of the supply chain), the actigram A2 delivers two possibilities of upgrade cycles format (number of cycles and duration of one cycle).

From a series of focus group, acceptability domains of upgradability for customer (sensible parts of product, price etc.) are identified. Using studies on external product aspects, as the analysis of Users trends, Competitors trends or technological trends during several generations, the future Value creation Themes for the product and for added services are identified. These Value creation themes are prioritised. The actigram A2 allows to define the targeted customer segments.

*4.3 Exploration of potential Value Network Structures (VaNS) and their transitions*

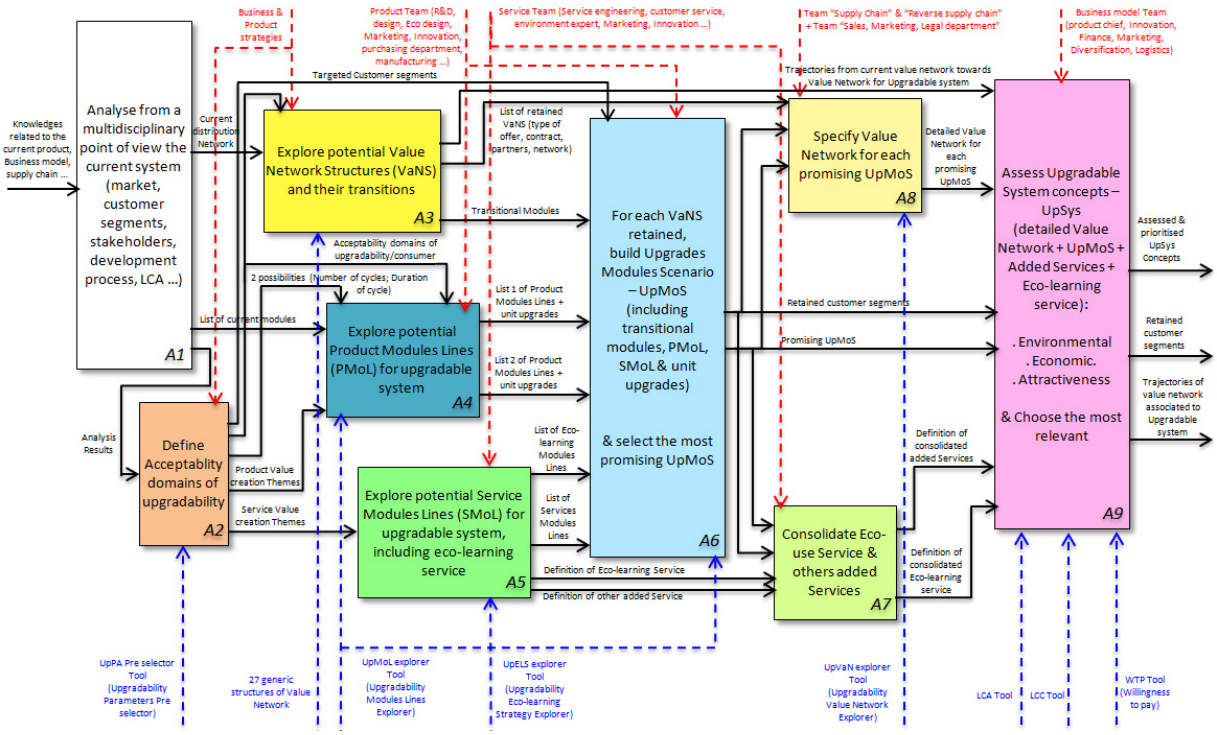
From Table of 27 generic structures of Value Network, the purpose of the actigram A3 is to explore offer type, contract mode and network with new partners in the short and long

term to form new potential Value Network structures (VaNS). This work is done related to business and product strategies department. To rely in progressive way the Value network in short-term and in long-term, trajectories of Value network change are defined. For each trajectory, strategic modules, which support the transition, are identified (transitional modules).

### *4.4 Exploration of potential Product Modules Lines (PMoL) for upgradable system*

Considering technological evolutions of the current modules, the new usage trends and the future Value creation themes, the actigram A4 proposes to explore all functional enrichments to bring to the product to generate a listing of potential upgrades. Then these upgrades are characterised by criteria like integration dates, over-cost, feasibility (etc.) and their contribution towards each Value creation theme (attractiveness criterion). From this work, upgrades lines can be defined. An upgrade line is a planning of upgrade integration with the goal to satisfy one or several Value creation theme(s). A list of unit upgrade is considered too. That's the optional/specific or not predictable upgrade.

Figure 1: Framework of method helping to define eco-innovative systems based on upgradability.




### *4.5 Exploration of potential Service Modules Lines (SMoL) for upgradable system, including eco-learning service*

From the future Value creation theme dedicated to services, the actigram A5 consists in exploring potential added services associated to an upgradable system. The goal is to design serviceable upgrade line in specifying technical impact on the product modules. More specifically eco-learning service is studied. An analysis of potential eco-usage drifts is leaded: compared to the prescribed usage, potential real usages are listed and their environmental impact is assessed. These eco-usage drifts are prioritised. Solutions to correct them are explored (eco-feedback; persuasive technology; new design etc.). An eco-learning service is imagined around an interaction between system and user supported by HMI (eg. Screen of smartphone).

### *4.6 Building and selection of the most promising Upgrades Modules Scenario – UpMoS (association of transitional modules, PMoL, SMoL & unit upgrades)*

The results of explorations during the phases A3, A4 and A5 allow to build Upgrades Modules Scenario (UpMoS). UpMoS is largely based on the association of the PMoL (A4) and the SMoL (A5). Unit upgrades complete the offer. The choice of upgrade sequences depends on the targeted customer segments (for whom?), the upgrade cycles format (when?) and the Value Network Structures (what business form?) retained (A3). To take into account the trajectory towards new business model, strategic transitional modules/upgrades are underlined. Because explorations A3, A4 and A5 are done independently, this association work must be done with help of the design and business teams. The Actigram A6 fix the most promising UpMoS which constitute

the starting point for consolidating/précising Value Network (A8) and eco-learning service (A7), and finally for forming Upgradable System concept (A9).

### *4.7 Consolidation of Eco-use Service*

Considering the programmed upgrades for each promising UpMoS, the purpose of the Actigram A7 is to identify potential new eco-usage drifts and take into account more precise functional definition of system to modify eco-learning solutions and interaction with user.

### *4.8 Specification of the Value Network for each promising UpMoS*

For each promising UpMoS, the Actigram A8 uncovers offer modalities encompassing upgrades of product and services, contract modalities (incomes; warranty; customer loyalty) and network modalities involving the choice of internal activities and partners, and the reverse supply chain definition related to the end-of-life strategy (replaced modules overtime and product structure at the end).

### *4.9 Multi-criteria assessment (environmental, economic and attractiveness) of Upgradable System concepts – UpSys (detailed Value Network + UpMoS + Added Services + Eco-learning service)*

The activity A9 is a phase of multi-criteria assessment and selection of the final concept (detailed Value Network + UpMoS + Added Services + Eco-learning service) in three criteria: acceptable for environment, viable economically for the company and attractive for the consumer. We proceed by 3 parallel evaluations, which can be independently made. Finally all the estimated concepts are organized into a hierarchy in on a trihedral for choice.

## 5. Conclusions

The objective of this research was to formalize a new method to help the design team to define eco-innovative systems based on upgradability. Upgradability implies to consider the whole system (product + service + supply chain etc. on multiple use-cycles) with an "extended" multidisciplinary design team and in a large view the environmental dimension (lifetime improvement by upgrades of modules and services, user consciousness with eco-learning service, business model including end-of-life treatment). The new ecodesign method proposed leads to choose the most promising solutions/options as early as possible in the design process, and responds to the general requirements for a good eco-innovative design approach.

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## References

[1] Dovì, V G., Friedler, F., Huisingh, D., and Klemeš, J J. (2009) Cleaner energy for sustainable future, Journal of Cleaner Production, Vol. 17, No. 10, pp.889–895.
[2] Lilley, D. (2009) Design for sustainable behavior: strategies and perceptions, Design Studies, 30, pp.704–720.
[3] Hirschl, B., Konrad, W., and Scholl, G. (2003) New concepts in product use for sustainable consumption, Journal of Cleaner Production, Vol. 11, No. 8, pp.873–881.
[4] SERI Research center, « Amis de la Terre » Europe, Report : Overconsumption? Our use of the world´s natural resources, p. 3, 2009.
[5] Ernzer, M., Lindahl, M., Masui, K. and Sakao, T. (2003) 'An international study on utilisation of design for environment methods (DfE) – a pre-study', Third International Symposium on Environmentally Conscious Design and Inverse Manufacturing, Japan.
[6] Fargnoli, M. and Kimura, F. (2006) 'Sustainable design of modern industrial products', 13th CIRP International Conference on Life Cycle Engineering, Leuven.
[7] Brezet H., Hemel C., (1997), ECODESIGN – A promising approach to sustainable production and consumption, UNEP publication, ISBN928071631-X.
[8] Millet, D., Tchertchian, N. and Brissaud, D. (2009) 'How to identify the most promising areas of environmental improvement at the early stages of the design process?', Int. J. Design Engineering, Vol. 2, No. 3.
[9] Millet, D., Bistagnino, L., Lanzavecchia, C. and Camous, R. (2005) 'Does the potential of the use of LCA match the design team needs?', Journal of Cleaner Production, Vol. 15, No. 4, pp.335–346.
[10] Fussler, C. and James, P. (1996) Driving Eco Innovation: A Breakthrough Discipline for Innovation and Sustainability, Pitman Publishing, London.
[11] Goedkoop, M., Effting, S. and Collignon, M. (2000) The Eco Indicator 99: A Damage Oriented Method for Life Cycle Impact Assessment-Manuel for Design, 2nd ed., Amersfoort, The Netherlands.
[12] Ernzer M., Oberender C., Birkhofer H. Methods to support ecodesign in the product development process. Going Green - Care Innovation 2002. Vienna, 2002.
[13] J. L. Chen, C-C. Liu, An eco-innovative design approach incorporating the TRIZ method without contradiction analysis, The Journal of Sustainable Product Design 1: 263–272, 2001.
[14] B Tyl, J Legardeur, D Millet, F Vallet, A comparative study of ideation mechanisms used in eco-innovation tools, Journal of Engineering Design 25 (10-12), 325-345, 2014.
[15] Hallmann, U., Herrmann, C., Maas, H. (2004) ProdTect, the Tool for Product Architects: Turning Challenges of Predicttive Design into Uniques Selling Points, Global Conference on Sustainable Product Development and Life Cycle Engineering, Berlin.
[16] Tseng H.-E., Chang C.-C., Li J.-D., Modular design to support green life-cycle engineering. Expert Systems with Applications,34:25, 2008.
[17] F.H. Beuren, M.G. Gomes Ferreira, P.A. Cauchick Miguel, Product-service systems: a literature review on integrated products and services (2013), Journal of Cleaner Production, Vol. 47, pp.222–231.
[18] G. Vasantha, R. Roy, A. Lelah, D. Brissaud, A review of product-service systems design methodologies, Journal of Engineering Design, 2012.
[19] James, P., 1997; 'The Sustainability Circle: a new tool for product development and design', Journal of Sustainable Product Design 2: 52:57
[20] Kimura F, Kato S, Hata T, Masuda T. Product modularization for parts Reuse in inverse manufacturing. Annals of CIRP, 50, 2001, pp.89-92.
[21] Wimmer, W. and Züst, R. (2003) 'ECODESIGN Pilot, product-investigation-, learning- and optimization-tool for sustainable product development', Alliance for Global Sustainability Book Series, Vol. 3.
[22] A. Osterwalder, Yves Pigneur, Alan Smith, and 470 practitioners from 45 countries, Business Model Generation, Wiley published, 2010.